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Population dynamics of *Carcharhinus melanopterus* caught from Southern Makassar Strait, Indonesia

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ABSTRACT

Blacktip reef shark *Carcharhinus melanopterus* is the species dominant catch of the traditional fisheries using bottom gill nets and bottom longline in South Sulawesi Province, Indonesia. This study aims to determine several *C. melanopterus* population dynamics parameters include growth rate, fishing mortality, exploitation rate, and relative yield per recruitment. Data collection of fish length was carried out from July to September 2020. Data were collected from all captured sharks landed at fish landing sites Paotere and Beba twice a week. Population growth is analyzed using the von Bertalanffy equation exponential growth, the value of L_∞, K, by ELEFAN method and t_0 by Pauly method. The total mortality (Z) was estimated from the catch curve, and the natural mortality (M) was obtained from Pauly's empirical relationship based on L_∞, K, and the mean temperature of the environment. FISAT-II software's help estimated the size of length at first capture (Lc). Finally, estimating the optimum level of exploitation rate (E) was carried out using the relative yield-per-recruit model (Y'/R) of Beverton and Holt. The results showed that the population of *C. melanopterus* in the Makassar Strait's southern waters had a low population growth rate with an infinity length (L_∞) of 161.5 cm and a growth rate coefficient (K) of 0.25 yr^{-1}, during the t_0 value of -0.4247 yr. The total mortality (Z) of 1.05 yr^{-1}, the natural mortality (M) of 0.45 yr^{-1}, fishing mortality (F) 0.6 yr^{-1}, and the size of length at first capture (L_c) of 99.64 cm. The estimated rate of exploitation (E) was below the optimum rate of exploitation. It seems that the population of *C. melanopterus* in this area is under-exploited.

Key words : *Blacktip reef shark, Population dynamics, Makassar Strait*

Introduction

Blacktip reef sharks *Carcharhinus melanopterus* are commonly found throughout tropical coral reef and coastal habitats (Chin *et al.*, 2013a). It is one type of reef fish that has a high economic value in Indonesia, so that it is suspected that there has been a decline in the condition of its stock. Shark fisheries in the southern Makassar Strait have not been used commercially, but because the high demand for shark exports has changed, the shark turns out to be the primary target. Sharks are exploited throughout the year using traditional fishing tools such as bottom long line and bottom gill net without a management policy. Although these fishing activities keep continuous, there is still very little research to reveal this problem.

The lower catch per unit effort (CPUE) indicates that shark fisheries resources have decreased (Fowler and Cavanagh, 2005). The growth of shark fisheries in Indonesia has exceeded production limits. This is indicated by the increasing difficulty of local fishers to catch sharks because the fishing locations are further away, the number of catches decreases, and the size that is caught is getting smaller (Fahmi and Dharmadi, 2013).

Shark's status is a potential change from vulnerable to overfishing. In order to recover the number of shark in one area, it takes an extended period. It is caused by some of the biological characteristics of sharks is a long life cycle reaching a maximum size of less than 180 cm total length, slow growth and sexual maturity with size at maturity (50%) both sexes: 95-110 cm and low fecundity (Compagno, 1984; Kyalo and Stephen, 2013; Stevens *et al.,* 2000). A report from (Mourier *et al.*, 2013) confirms that *C. melanopterus* males reached sexual maturity at 111 cm. The maximum age from wild-caught individuals is estimated to be 15 years; however, captive animals have lived for > 25 years (Chin *et al.,* 2013b). This study evaluates the condition of *C. melanopterus* stock in the southern Makassar Strait Waters using several population dynamics parameters, including population growth rate, fishing mortality rate, probability of capture, exploitation rate, and relative yield per recruitment.

Materials and Methods

Description of the study sites

The research location is focused on 2 fish landing site, which are the main landing sites for *C. melanopterus*. Location of study and area of sampling i.e at the site of fish landing Paotere, Makassar City, and the site of fish landing Beba, Regency Takalar, Province South Sulawesi, Indonesia. Fish sampling locations were as shown as presented in Figure 1.

Data collection and data analysis

This study was conducted from July to September 2020 in the southern Makassar Strait Waters. *C. melanopterus* fish samples were obtained from the number of fishermen's catch that landed at the two fish landing sites using *in situ* measurements. Data that measured was the total length (TL: cm). Length frequency data is collected twice a week from the bycatch of bottom longline and bottom gill nets of the traditional fishery. Length data were grouped into 5 cm length groups, and the midpoint is used for the study.

In this study, population parameters as length asymptotic (L_∞) and growth coefficient (K), natural mortality (M) and fishing (F), rate of exploitation (E), and relative yield per recruitment (Y'/R) of *C. melanopterus* were estimated based on monthly length-frequency data using FiSAT II software (Gayanilo *et al.*, 2005).

The von Bertalanffy's growth curve (Sparre *et al.*, 1989) as follows: $L_t = L\infty[1-e^{-K(t-to)}]$, where: L_t = length of fish at time t (cm), L_∞ = asymptotic length (cm), K = the growth coefficient ($year^{-1}$).

The value of asymptotic length and growth coefficient were estimated using monthly data percentage in the ELEFAN-I by the Response Surface method of FiSAT II. Estimates of growth parameters

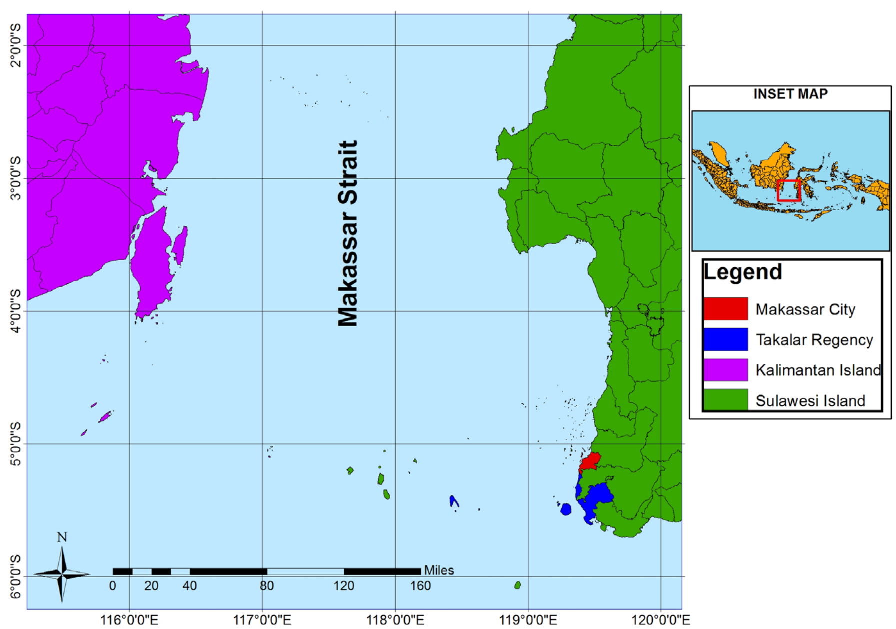

Fig. 1. Research Location

were obtained from the L_∞ and K pairs, which gave the highest Rn value (Rn = 10ESP/ASP/10). t_0 - the hypothetical fish age at zero-length (yr). t_0 was determined using the empirical formula of Pauly (1980), as follows:

$$\text{Log}(-t_0) = -0.3922 - 0.2752\,(\text{Log}\,L_\infty) - 1.038\,(\text{Log}\,K)$$

The total mortality rate (Z) was calculated using the length converted catch curve method by FiSAT II (Gayanilo *et al.*, 2005; Pauly, 1983). Length converted catch curves are created by plotting ln (Ni / Δt) against relative age t_i. A first estimate of Z is obtained when the following function is adjusted to the points of the right descending arm of the catch curve: $\ln(N_i / \Delta t_i) = a + b\,t_i$ where, N_i is the number of fish in length class i, Δt_i is the time needed for the fish to grow through length class i, t_i is the age (or the relative age) corresponding to the mid length of class i, and where b, with the sign changed, is an estimate of Z.

Natural mortality rate (M) was calculated using the empirical formula of Pauly (1980) with a mean annual surface temperature (T) of 28°C as follows: $M = \text{Exp}(-0.152 - 0.279\,(\ln L_\infty) + 0.6543\,(\ln K) + 0.4634\,(\ln T^{o}C))$

Where: M = natural mortality rate (yr^{-1}), L_∞ = Infinity Length (cm), K = coefficient of growth rate ($year^{-1}$), and T = average temperature of the water (^{0}C).

Mortality rate of fishing (F) estimated using the equation: F = Z – M (Pauly, 1980; Pauly, 1983). As for the rate of exploitation (E) E = F / Z. The size of length at first capture (L_c) is analyzed based on the estimated logistic curve or the estimated selection ogive function (S_{Lest}) in the following equation (Sparre *et al.*, 1989):

$$SL_{est} = \frac{1}{1 + \exp(S1 - S2^{*} L)}, \quad L_c = S1/S2$$

Where: SL_{est} - the estimated logistic curve or the estimated selection ogive function

S1 - the intercept, S2 - the slope in logistic curve.

L_c was computed using the FISAT-II tool (Gayanilo *et al.*, 2005).

Relative yield per recruit (Y'/R) model of Beverton and Holt (Sparre *et al.*, 1989) as follows:

$$(Y'/R) = E.\,U^{M/K}\left(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right)$$

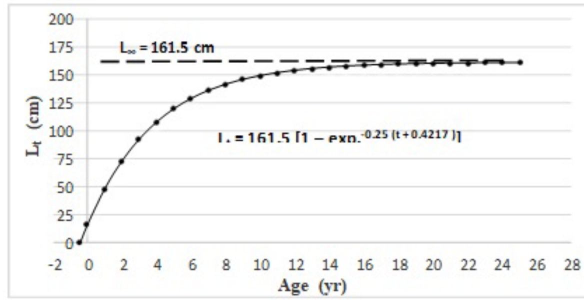

Fig. 2. Growth curve of *Carcharhinus melanopterus* in southern Makassar Strait Waters

Where:

$$U = 1 - \frac{Lc}{L\infty}, \quad m = \frac{1-E}{M/K} = K/Z, \quad \text{and} \quad E = F/Z$$

Where: E = rate exploitation; U = the fraction of the growth to be completed after entry into the exploited phase;

K = coefficient growth rate (yr^{-1}); L∞ = asimptot fish Length (cm); L_c = size of the smallest class of fish caught (cm); and M = natural mortality rate (yr^{-1}).

Results

Growth - The value of the von Bertalanffy growth equation for *Carcharhinus melanopterus* was estimated that L_∞ was 161.5 cm, K was 0.25 yr^{-1}, and Rn was 0.425 at SS=2 and SL=77.5. t_o was -0.4217 yr. Based on K, L_∞, and t_0 values obtained above, the exponential growth equation of von Bertanlanffy of *C. melanopterus* in the southern Makassar Strait Waters could be written as follows: L_t = 161.5 [1 – exp.-

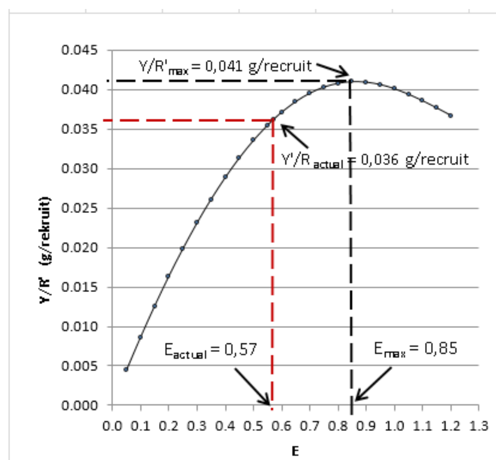

Fig. 3. Graphic relative yield per the recruitment of *Carcharhinus melanopterus* in southern Makassar Strait Waters

$^{0.25\,(t+0.4217)}$]. In using von Bertalanffy growth equation, the age of every length of fish can be predicted easily (Figure 2), as follows:

Mortality and Exploitation Rate - Using the $L\infty_=$ 161.5 cm and K = 0.25 yr^{-1} obtained through ELEFAN I and M = 0.45 yr^{-1} from Pauly's (1980) empirical relationship, the estimated value of total mortality (Z) obtained from the catch curve is Z = 1.05 yr^{-1}, which result in fishing mortality (F) = 1.05 - 0.45 = 0.60 yr^{-1}. Hence the exploitation rate (E = F/Z) was 0.57. A value of L_c = 99.64 cm was obtained.

Relative Yield per Recruitment. The yield per recruit was determined as a function of the exploitation rate, assuming $L_c/L\infty$ and M/K are 0.6592 and 1.76, respectively. The plot of relative yield per recruit (Y'/R) against E is shown in (Figure 3), where the maximum Y'/R (0.041) was obtained at E_{max}= 0.85, and as the exploitation rate increases beyond this value, relative yield per recruit decreases. In this research the value of actual Y'/R obtained was 0.036 (E = 0.57) less than optimal value of Y'/R was 0.04 (E = 0.85) (Figure 3).

Discussion

The value of von Bertalanffy growth equation parameters (Figure 2) shows no difference compared with the L∞ and K values estimated by other researchers for the same species from different waters. A report from (Chin *et al.,* 2013b) said that the value of asymptotic length (L_∞) = 1585 mm LST; K (from logistic model) = 0.251 yr^{-1} for *C. melanopterus* from north-eastern Australia. There is regional variation in growth, and the maximum size is generally less than 160 cm though individuals have been recorded up to 180 cm (Mourier *et al.*, 2013; Papastamatiou *et al.,* 2009). Different methods, different data, and factors of habitats' eco-biological conditions from time to time may be used to produce different results.

In this research, the rate of exploitation was 0.57. A statement from Mallawa (2012) explained that the exploitation rate is categorized high if E > 0.5. If the actual exploitation rate value is related to the maximum exploitation rate value, then the actual value for *C. melanopterus* in the Makassar Strait's southern waters is still below its optimum value (E_{max} =0.85), so that its status is still underexploited. It is mainly carried out as by catch at bottom gill nets and bottom longline fisheries.

Based on the von Bertalanffy growth equation obtained, the age of the *C. melanopterus* at the first time it was caught (L_c) was 3.417 year. The estimated L_c value above indicates that the average size of the *C. melanopterus* caught by the fishing gear is a group of young fish. To maintain the availability of *C. melanopterus* species stock, efforts are made to increase the L_c value so that the *C. melanopterus* minimum caught by the fishing gear has spawned with *a total length > 111 cm. Report from* (Chin *et al.,* 2013b; Mourier *et al.,* 2013) said that *C. melanopterus* for males matured at 4.2 yr (1050 mm L_{ST}) and females at 8.5 yr (1335 mm L_{ST}).

The current exploitation rate of *C. melanopterus* based on mortalities rate, E=0.57, is lower than E_{max} and E_{MSY} based on relative yield per recruit analysis. Based on Figure 3, if we intend to keep the *C. melanopterus* population in equilibrium condition (Y'/R optimum), the rate of exploitation of the *C. melanopterus* population must be increased. A Beverton-Holt relative yield per recruit (Y'/R) model explored that the exploitation rate is underfishing less than 27.06% for E_{max}.

Conclusion

- The population of *Carcharhinus melanopterus* in the southern Makassar strait dominated by small fishes and grow was slowly.
- The values of dynamic population parameters were not to difference with the population of *C. melanopterus* in the specific fishing area, and the natural death less than the death because of the fishing.
- To maintain the population in equilibrium condition, the number (biomass) of fishes recruited must be increasing by increasing the size of the fish caught.
- The rate of exploitation of *C. melanopterus* is currently low more than the optimal exploitation rate.

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